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Test on Application of Flame Detector for Large Space Environment

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Abstract

This paper analyzes and studies the applicability of video image, infrared and ultraviolet/infrared (UV/IR) flame detectors for high and large spaces, atrium in particular, and a test simulating the actual working conditions and typical interference from ambient light is designed based on the operation principles of flame detectors and their operation limits to offer important testing methods and data for the research on applications of flame detectors to large space locations and fire prevention design.

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Keywords: atrium; flame detector; ambient light interference test; applicability

1. Introduction

With the rapid development of China's economy, the number and size of large space buildings including large convention center, stadium, exhibition hall and large shopping mall (supermarket) are increased. As these buildings are characterized by large area, high lift frame, complex structure, intensive personnel, property and equipment and greater fire load, they has been the focus of fire prevention and control and fire safety. In recent years, the atrium concept has been accepted and used by more and more architects, and this architectural form has been widely applied to various types of public buildings, such as shopping malls, hotels, libraries, hospitals, apartment complexes and entertainment centers. As an effective means to monitor the open flame fire, flame detector uses non-contact detection method, featuring long detection distance and larger protection scope and is one of the fire detection equipment that is widely used in large space fire detection and monitoring. Infrared flame detector, dual-band and multi-band infrared flame detector, UV detector and UV/IR detector, and video image type flame detectors are among the most common types [1].

In practical engineering applications, high and large space buildings, especially atriums, are characterized by multiple functionalities, large volumes of storage, intensive occupants and complex surroundings, and flame detector has many internal interference sources in the building [2], and the most important and most complex effects on the stable operation and reliable detection of flame detectors come from the typical sources of interference such as the building's interior lighting and decorative lighting. Therefore, the adaptability of the flame detector in such buildings to the interference from typical ambient light is important, and it largely determines whether such a detector can be used in buildings with large spaces, especially in large spaces like atrium, for reliable and rapid detection of naked flame sources, to achieve reliable fire monitoring.

At present, the environment adaptability of flame detectors has become the hotspot of studies on the applications of fire detection for large indoor spaces and draws wide attention from fire researchers and research institutions domestic and abroad alike. However, since such researches require more complicated testing environment, testing objects and methods,

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there is still no comprehensive and accurate results and presently there is less researches that use ambient light from the external environment as the source of interference, thus no design method and specifications ever developed [3].

In this regard, as members from the project of Study on Fire Detection Application Technology for Complex Building Atrium, we conduct the study on the adaptability of flame detector to environment of atrium in buildings. Based on survey and analysis of the functionalities and environment characteristics in high and large buildings, large spaces like atrium in particular, as well as the operation principles of flame detector, a test on the performance of spot type flame detector and video image type flame detector in resisting the interference from typical ambient light from the external environment is designed, targeting the interference from ambient light from the external environment, which have the most important and significant factor affecting the flame detector used in high and large spaces. The test is intended to examine the reliability and effectiveness of several types of flame detectors used in fire detection for buildings with large spaces, and provides practical referential information for the design and applications of fire detection and alarming systems used in large spaces such as atrium.

2. Test Design

Spot type flame detector (IR flame detector and UV/IR flame detector) is one of the fire detection devices applied in fire safety design for large spaces as required by current related specifications, and like video image type flame detectors, it features longer detection distance and wide protecting range, applying for naked fire source detection in high and large architectural spaces. Based on the detection operation principles of spot type flame detector and video image type flame detector, i.e. detecting the presence of flame by perceiving electromagnetic radiation in a particular band and through flame's optical imaging characteristics, as well as our study and analysis on the functionalities and environment characteristics of large space buildings, we observe that within the high and large space buildings, large space locations like atrium in particular, lighting and decorative light source are the most obvious and critical interference to the above two kinds of flame detection [5]. Hence, with this respect, we design a test on the performance of spot type flame detector and video image type flame detector in resisting the interference from typical ambient light from the external environment to test the reliability and effectiveness of such flame detectors in detecting the naked fire source in large spaces within buildings by simulating the interferences from lighting, decorative and stage light sources within buildings under the actual operating conditions.

2.1. Testing Site

In this research, we use the large space laboratory to simulate the large spaces such as atrium. Considering the limitations on effective detection distance and protection range of the typical spot type and video image type flame detectors and the requirements on facilitating the regular testing and maintenance in engineering applications, and referring to site design in related large space fire experiments and in specifications on fire detector response threshold value test as in *GB 15631-2008 Special Type Fire Detectors*, we place the dual IR flame detector, UV/IR flame detector and the video image type flame detector vertically on one side of walls of the laboratory, at the locations 3 m and 5 m from the floor respectively, with a depression angle of 45° to monitor the site, as shown in Fig. 1.

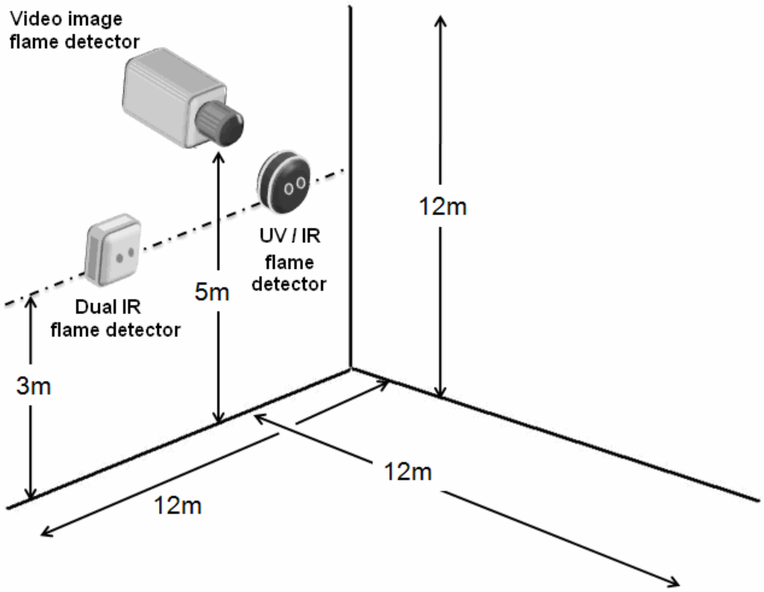

Fig. 1. location of flame detectors

2.2. Selection and design of ambient interfering light sources

According to the requirements for lighting source in high and large spaces such as shopping halls and industrial plants specified in *Standard for Lighting Design of Buildings* (GB 50034-2004) and field survey of such large spaces, we select metal halide lamps and high-voltage gas discharge lamp commonly used in shopping halls and industrial plants as the primary light sources.

According to *Standard for Lighting Design of Buildings* (GB 50034-2004), the value of illumination in large spaces such as shopping halls and industrial plants is generally required within the range of 200－500 lx. Hence, we designate the standard illumination in the large space laboratory for this test to be 850 lx [6], and use the general illumination formula [6], [7]:

$$E = \varphi \cdot \eta_{(LM)} \cdot \eta_m \cdot RI / A \tag{1}$$

Where, E represents Illumination level;
φ is total flux;
$\eta_{(LM)}$ represents luminaires efficiency;
η_m is maintenance factor;
RI is room index;
A stands for area;
and luminaires efficiency takes 0.6; maintenance factor takes 0.7; room index takes 1.7 (average height of luminaires: 3.5 m).

Calculation concludes that the total flux for the interference light source in this large space laboratory shall be set approximately at 170,000 lm.

The lighting system of the interference light source comprises the following lamps on the basis of the above calculation.

Table 1 Lamps Used as Interfering Light Sources

Description	Operating voltage/power	Flux	Color temperature	Quantity
HID sodium vapor lamp	220V/400W	48000lm	2000K	1
Metal halide lamp	220V/400W	38000lm	4000K	1

Bromine tungsten lamp	220V/800W	12000lm	3200K	2
Halogen tungsten lamp	220V/500W	9500lm	2800K	6
Halogen lamp	220V/50W	600lm	3000K	10

In addition, according to the regulations on decorative light source in *Standard for Lighting in Entertainment Halls and for Restricting Pollution from Light Therein* (WH0201-94) and the field survey results of buildings such as large shopping hall and supermarket, we designed a group of decorative interfering light source with a number of commonly used decorative lamps, including 4 strobe lamps in white, yellow, red and blue each, 1 ceiling stage lantern, 1 stage rotating floor lamp, 16 exhibition stand decorative color halogen lamps and a row of LED neon lamp. Referring to the installation height and angle of lighting system in general buildings, interfering and decorative light sources are installed on the special light source stand of 2.5 m－3.5 m in height 10 m away from the detectors [8], as shown in Fig. 2(a) and (b).

(a) (b)

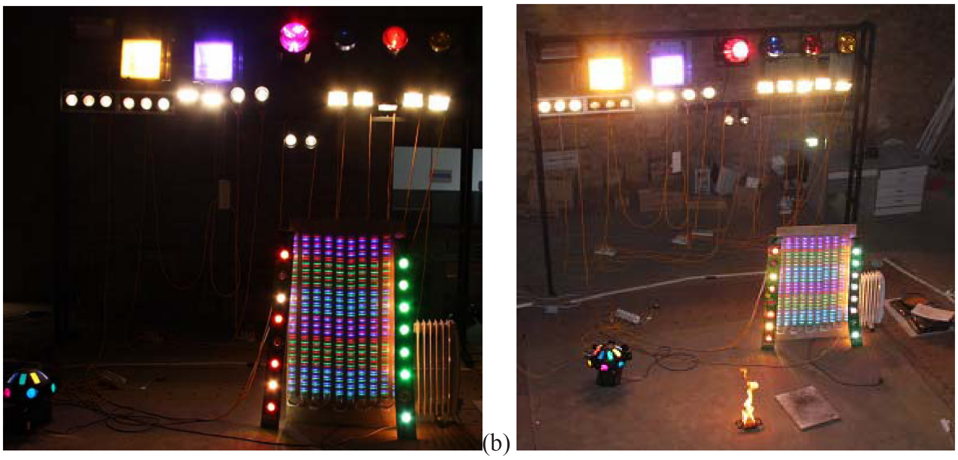

Fig. 2. Integrated Panel of Interfering Light Sources

2.3. Test content

According to the operation principles of flame detector and video image flame detector, the interference from the interfering light source on the flame detector and video image flame detector is mainly through the direct and indirect exposure to light to affect the on the functions of the detector, resulting in unstable operation and fire detection within the protection range. Therefore, the test of ambient light interference resistance performance of flame detector and video image flame detector is on the basis of the relative location of detector to the interfering light source, type of interfering light source and test types. The test is detailed in Table 2.

Table 2 Contents of Test on Performance of Resisting Interference from Typical Environment Lights

Test No.	Test Description	Test Content
1	Stable operation and interference test under indirect exposure to lighting source	30 minutes of stable operation, frequent on-off of parts of light sources, movement of objects within the protected area under the light sources, etc.;
2	Alarming function test under indirect exposure to lighting source	Test the detection and alarm functions of each detector to 0.01 m^2 n-heptane fire in the protected area, and record the response time;
3	Stable operation and interference test under direct exposure to lighting source	30 minutes of stable operation, frequent on-off of parts of light sources, movement of objects within the protected area under the light sources, etc.;
4	Alarming function test under direct exposure to lighting source	Test the detection and alarm functions of each detector to 0.01 m^2 n-heptane fire in the protected area, and

		record the response time;
5	Stable operation and interference test under indirect exposure to stage decorative lighting source	30 minutes of stable operation, adding some extra light sources, movement of objects within the protected area under the light sources, etc.;
6	Alarming function test under indirect exposure to stage decorative lighting source	Test the detection and alarm functions of each detector to 0.01 m^2 n-heptane fire in the protected area, and record the response time;
7	Stable operation and interference test under direct exposure to stage decorative lighting source	30 minutes of stable operation, adding some extra light sources, movement of objects within the protected area under the light sources, etc.;
8	Alarming function test under direct exposure to stage decorative lighting source	Test the detection and alarm functions of each detector to 0.01 m^2 n-heptane fire in the protected area, and record the response time;
9	Stable operation and interference test under indirect exposure to neon light and exhibition stand decorative light	30 minutes of stable operation, adding some extra light sources, movement of objects within the protected area under the light sources, etc.;
10	Alarming function test under indirect exposure to neon light and exhibition stand decorative light	Test the detection and alarm functions of each detector to 0.01 m^2 n-heptane fire in the protected area, and record the response time;
11	Stable operation and interference test under direct exposure to neon light and exhibition stand decorative light	30 minutes of stable operation, adding some extra light sources, movement of objects within the protected area under the light sources, etc.;
12	Alarming function test under direct exposure to neon light and exhibition stand decorative light	Test the detection and alarm functions of each detector to 0.01 m^2 n-heptane fire in the protected area, and record the response time;

The alarming function test uses 0.01 m^2 n-heptane fire as the naked fire for alarming function test according to the fire sensitivity test on spot type IR fire detector as specified in *GB 15631-2008 Special Type Fire Detectors*.

3. Test Results and Analysis

Test data on stable operation and alarming function of the detectors from the careful testing are detailed in Table 3 and Table 4.

Table 3 Detector Stable Operation Test Data

Test Item / Detector	30 minutes of stable operation (No. of false alarms/No. of tests)	Power on-off of light source (No. of false alarms/No. of tests)	Movement of object under light source and others (No. of false alarms/No. of tests)
Video image flame detector	0/40	0/40	2/40
Dual IR flame detector A	1/40	2/40	1/40
Dual IR flame detector B	0/40	1/40	0/40
UV/IR flame detector	0/40	0/40	0/40

Table 4 Detector Alarming Function Test Data

Test Item / Detector	0.01m^2 n-heptane fire alarming function (No. of alarms/No. of tests)	Average alarming time (sec.)
Video image flame detector	40/40	2.1
Dual IR flame detector A	38/40	8.4
Dual IR flame detector B	39/40	10.1
UV/IR flame detector	40/40	3.4

Test data indicate that in case of direct or direct exposure to the lighting source and decorative lights, since the two bands of dual infrared flame detector concentrate in the infrared band, the movement of light will give occasional false alarms during operation when infrared radiation is significant, but the false alarm rate is lower; the afterglow effect that moving decorative color lamps have on the imaging of video image flame detector and the presence of imaging information resembling to flame cause false alarms by the video image flame detector, but the false alarm rate is lower. In detecting the flame of naked fire under the interference from ambient light, the detection sensibility and fire response capability of the dual IR flame detectors are affected to some extent due to the detectors need compensation for the interference from the environment light.

On the basis of the above test data, we draw conclusions that the flame detectors of different types that we used in the test all achieve reliable and stable operation under the ambient light from external environment of illumination levels exceeding the standard requirements for the large space locations and can provide timely reliable detection of the experimental fire source within the protected area, presenting strong performance in resisting interference from ambient light and reliable detection and alarming capabilities. In a relative term, the video image flame detector used in this test has the fastest response speed and excellent flame detection performance. The UV/IR flame detectors do not have false alarm and have the strongest reliability; their response time varies little under interference from a variety of types of ambient light sources, presenting good immunity and resistance to the interference from typical ambient environment lights in large building spaces such as atrium, as well as rapid response speed to flame.

4. Conclusion

With the wide adoption of high and large spaces such as atrium in architecture and buildings, such structures and their complicated functionalities require that the fire prevention and control in buildings shall be focused on the preventive measures, asking for early detection and timely control. Flame detectors can be provided in the large space locations such as atrium, and in case of any naked fire, the flame detectors enable early fire detection, helping in early fire extinguishment and fire control, allowing more evacuation time, and improving fire extinguishment and rescue effectiveness.

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